

(12) UK Patent Application (19) GB (11) 2 023 797 A

(21) Application No 7920872
(22) Date of filing
15 Jun 1979
(23) Claims filed
15 June 1979
(30) Priority data
(31) 916388
(32) 16 Jun 1978
(33) United States of America
(US)
(43) Application published
3 Jan 1980
(51) INT CL³ F02B 29/04
(52) Domestic classification
F4S 14
F4U 24A1
(56) Documents cited
GB 1167264
GB 1033181
GB 987429
GB 859708
GB 806577
GB 688246
GB 688245
GB 688191

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second heat exchanger 48 which
transfers heat from the charge air to
ambient air.

(54) Charge air cooling systems

(57) A charge air cooler 44 for a
turbocharged engine 12 comprises
a first heat exchanger 46 which
transfers heat from the charge air
(in line 32) to the engine cooling
water (in conduits 50, 52), and a

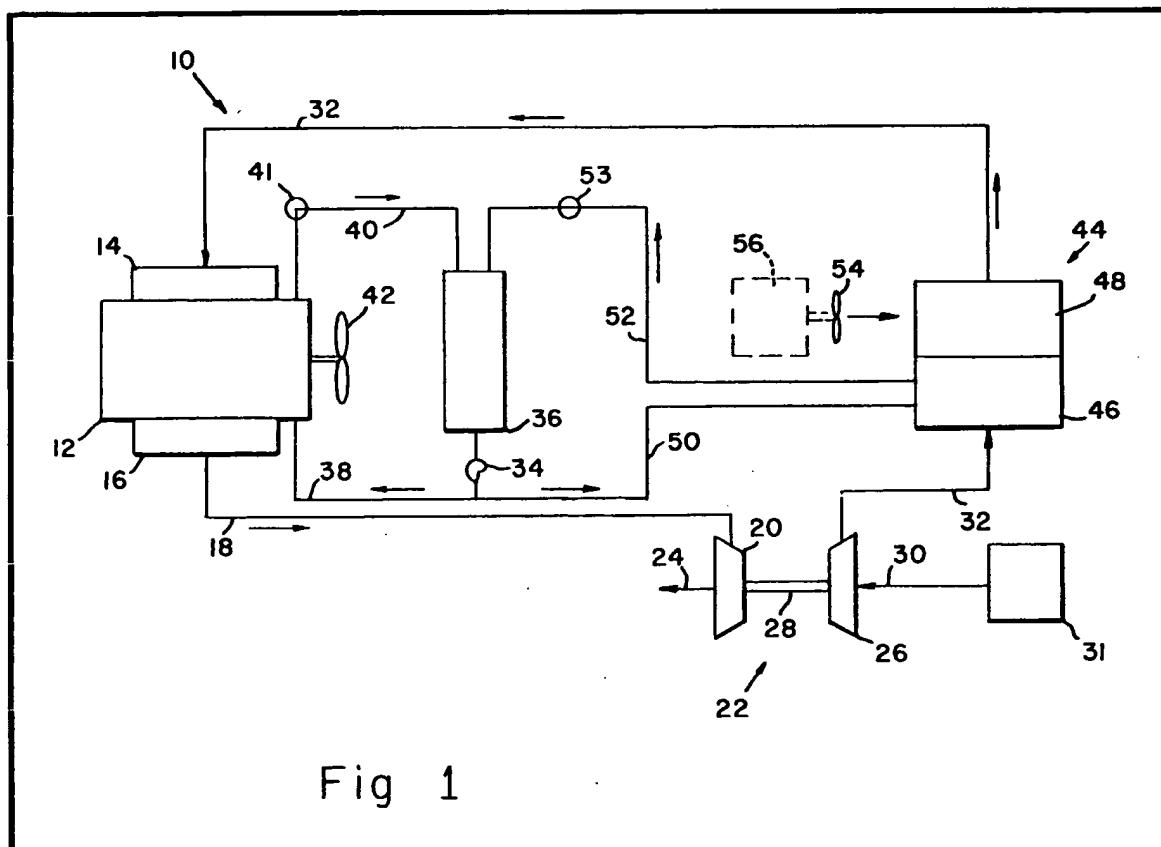
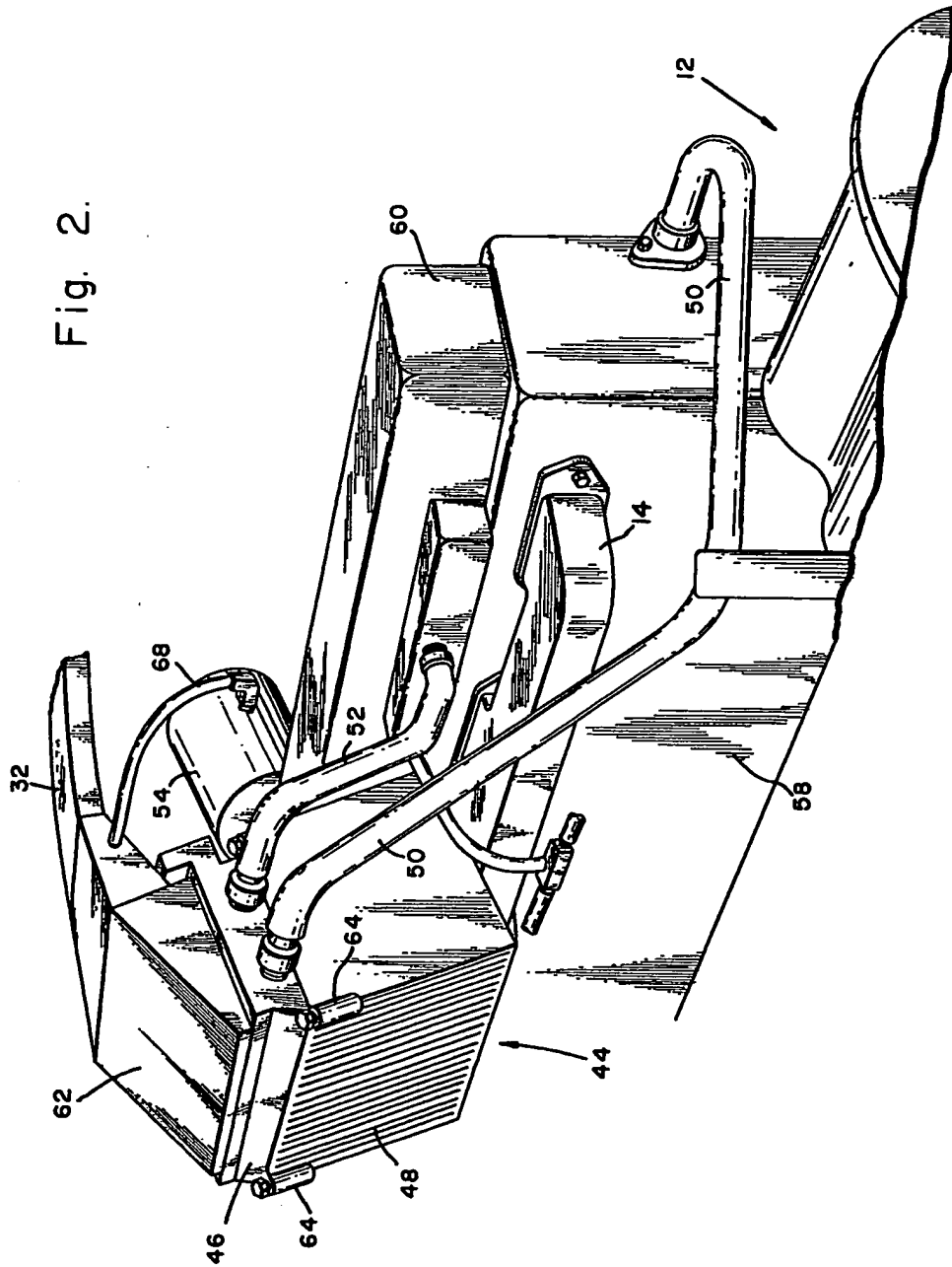


Fig 1

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Fig. 2.



SPECIFICATION

Charge air cooling system

5 This invention relates to charge air cooling systems. It is particularly applicable to systems for cooling compressed charge air supplied to engines.

The object of charge air cooling is to increase the density of the charge air supplied to the engine, so that the engine can develop increased power. Charge air cooling also reduces the overall heat load on the engine. Normally, charge air cooling is adopted where some form of pressure-charging is used, such as turbo-charging or supercharging, since the charge air will be heated by its adiabatic compression.

Thus, according to one aspect of the invention, a charge air cooling system for fuel-burning apparatus comprises a first air-to-liquid heat exchanger arranged to cool charge air flowing along a charge air path, and a second air-to-gaseous coolant heat exchanger connected to receive cooled charge air from the air-to-liquid heat exchanger and to cool such charge air further.

With such a system, the air-to-gaseous coolant heat exchanger does not have to handle the whole of the heat to be removed from the charge air, and therefore it can be of a relatively small size. The air-to-liquid heat exchanger handles the remainder of the heat load; because such a heat exchanger is, in general, smaller than an air-to-gas heat exchanger of the same capacity, it will be appreciated that the whole charge air cooling system may be made smaller than if the whole of the cooling were performed by an air-to-gas heat exchanger. At the same time, the temperature to which the charge air can be cooled will not be limited to the lowest temperature at which a liquid coolant is available, since the heat transfer to a liquid coolant in the first heat exchanger is followed by heat transfer to a gaseous coolant in the second heat exchanger. In a typical application, the liquid coolant will be engine cooling water while the gaseous coolant will be ambient air; it will be appreciated that the former will usually be at a considerably higher temperature than the latter. Thus, the invention should allow charge air to be cooled to a temperature not far above ambient, without the need for a particularly large heat exchanger, and without the use of any kind of refrigerating system.

It will be appreciated that a large heat exchanger is particularly inconvenient in a vehicle application.

The invention also provides, according to a second aspect, a pressure-charging system for an engine, which system comprises a charge air compressor connected to supply compressed charge air to a charge air cooling system according to the first aspect.

The invention also provides, according to a third aspect, an engine installation comprising an engine, and a pressure-charging system according to the second aspect, connected to supply cooled, compressed charge air to the engine.

The invention may be carried into practice in various ways, and one specific embodiment will now be described by way of example, with reference to the accompanying drawings, of which:—

Figure 1 is a schematic diagram of a turbo-charged engine installation using the invention; and

Figure 2 is a perspective view of part of the installation of *Fig. 1*.

The engine installation (referenced 10 in *Fig. 1*) comprises an engine 12, illustrated in *Fig. 2* as an in-line engine, a radiator 36, a turbocharger 22, and a charge air cooler 44. The turbocharger 22 includes a turbine 20 which is driven by exhaust gases received from an exhaust manifold 16 of the engine through an exhaust line 18; the exhaust gases leaving the turbine 20 pass to atmosphere through a line 24. The turbine 20 is mounted on a shaft 28 which also carries a compressor 26; the compressor 26 draws in air from the atmosphere through an air filter 31 and an intake line 30, and delivers compressed air through a line 32, which leads, through the charge air cooler 44, to an inlet manifold 14 of the engine 12. Thus, the compressed air will be cooled before reaching the engine, thereby increasing the mass of air entering the engine cylinders and allowing the engine to develop increased power.

The radiator 36 and the engine 12 are connected by conduits 38 and 40 to form a cooling circuit. In operation, liquid coolant (usually water, or water-based) is pumped from the radiator to the engine through the conduit 38 by an engine-driven pump 34. After absorbing heat in passing through cooling passages in the engine 12, the coolant returns through the conduit 40 to the radiator 36, where heat is transferred from the coolant to atmospheric air. A cooling fan 42, which is illustrated as being driven by the engine 12, provides a flow of air over the radiator 36, to increase the cooling of the coolant. A flow-regulating thermostatic valve 41 is provided in the conduit 40, to control the flow of coolant in dependence on its temperature.

The charge air cooler 44 includes an air-to-air heat exchanger 48 which, as *Fig. 2* shows, is mounted on top of and slightly to one side of the engine inlet manifold 14. The charge air cooler also includes an air-to-liquid heat exchanger 46 which is mounted on top of the heat exchanger 48 by means of bolts 64 (*Fig. 2*). Compressed air from the line 32 is led into the top of the charge air cooler by an upper header 62, and flows downwards, first through the air-to-liquid heat exchanger 46

and then through the air-to-air heat exchanger 48, and then reaches the inlet manifold 14.

The air-to-liquid heat exchanger serves to transfer heat from the compressed charge air to a liquid coolant which is led to and from the heat exchanger by conduits 50 and 52. In this example, the conduits 50 and 52 are coupled, respectively, to the delivery side of the pump 34, and to the inlet end of the radiator 36, so that the heat exchanger 46 is effectively in parallel with the engine 12. In fact, as Fig. 2 shows, the connection of the heat exchanger 46 in parallel with the engine can be accomplished by connecting the conduits to appropriate points on the engine 12; Fig. 2 shows the conduit 50 connected to the cylinder block or cylinder head (collectively shown as 58 in Fig. 2) of the engine, and the conduit 52 connected to an inlet provided beside the valve cover (shown at 60 in Fig. 2). The conduit 52, like the conduit 40, may include a thermostatic valve 53 which controls the coolant flow in dependence on the coolant temperature.

The air-to-air heat exchanger 48 serves to cool the compressed air further, by heat transfer to a flow of atmospheric air which is produced by a fan 54 driven by some kind of motor 56. In this example, as Fig. 2 shows, the motor is pneumatically driven by a flow of compressed air bled from the line 32 through a line 68.

Other arrangements are possible. For example, the conduit 52 may direct the coolant leaving the heat exchanger 46 to the thermostatic valve 41, so that the valve 53 can be eliminated. Alternatively, the heat exchanger 46 can be controlled in dependence on the temperature of the charge air arriving at the charge air cooler 44, or a thermostatically-controlled bypass may be provided between the conduits 50 and 52. It is also possible for the two heat exchangers 46 and 48 to be physically separated from one another. This may be convenient, since other methods than those mentioned above may be used for cooling the radiator 36 and the heat exchanger 48. For example, the heat exchanger could be cooled by the fan 42, or by a flow of air created by the movement of a vehicle propelled by the engine installation 10. The fans 42 and 54, if used, can be hydraulically, pneumatically, electrically or mechanically driven. The form of the heat exchangers 46 and 48 is not critical to the invention; possible types are plate-fin and tube-fin heat exchangers.

It should also be understood that the invention is not limited to the use of an exhaust-driven turbocharger; other forms of supercharger can also be used.

CLAIMS

1. A charge air cooling system for fuel-burning apparatus comprising a first air-to-

liquid heat exchanger arranged to cool charge air flowing along a charge air path, and a second air-to-gaseous coolant heat exchanger connected to receive cooled charge air from the air-to-liquid heat exchanger and to cool such charge air further.

2. A system as claimed in Claim 1 in which the second heat exchanger is an air-to-air heat exchanger.

3. A system as claimed in Claim 2 in which the second heat exchanger is arranged to transfer heat from the charge air to atmospheric air.

4. A system as claimed in Claim 1 or Claim 2 or Claim 3 which also includes means arranged to circulate a liquid coolant through the first heat exchanger.

5. A system as claimed in Claim 4 which also includes a thermostatic valve arrangement for controlling the rate of circulation of the liquid coolant through the first heat exchanger.

6. A system as claimed in any of the preceding Claims, which also includes a radiator coupled to the first heat exchanger, to form a circulating path for a liquid coolant.

7. A system as claimed in any of the preceding Claims, which also includes means arranged to direct a flow of gaseous coolant through the second heat exchanger.

8. A system as claimed in Claim 7 in which the said flow directing means is a fan.

9. A system as claimed in any of the preceding Claims, in which the first and second heat exchangers are mounted one on the other, in such a way that charge air passes directly from the first to the second heat exchanger.

10. A pressure-charging system for an engine, the system comprising a charge air compressor connected to supply compressed charge air to a charge air cooling system as claimed in any of the preceding Claims.

11. An engine installation comprising an engine, and a pressure-charging system as claimed in Claim 10, connected to supply cooled, compressed charge air to the engine.

12. An installation as claimed in Claim 11 when appendant to Claim 6, in which the radiator is also coupled to cooling passages in the engine, to form a cooling system for the engine.

13. An installation as claimed in Claim 12 when appendant to Claim 4, in which the liquid coolant circulating means circulates coolant from the radiator to both the first heat exchanger and the engine.

14. A charge air cooling system for fuel-burning apparatus, the cooling system being substantially as herein described, with reference to the accompanying drawings.

15. An engine installation including a charge air cooling system as claimed in Claim 14.

16. A charge air cooling system compris-

- ing a first heat exchanger having dual fluid flow paths for receiving a supply of charge air in heat exchange relation with a liquid coolant; a second heat exchanger having dual fluid flow paths for receiving the supply of charge air from said first heat exchanger in heat exchange relation with a gaseous coolant; and means for supplying the charge air serially to said first and second heat exchangers.
17. A charge air cooling method comprising the steps of supplying charge air to a first heat exchanger having dual fluid flow paths in heat exchange relation with a liquid coolant; and supplying the charge air from said first heat exchanger to a second heat exchanger in heat exchange relation with a gaseous coolant.
18. A charge air cooling method comprising the steps of supplying charge air through one flow path of a first heat exchanger having dual fluid flow paths; circulating a liquid coolant through the other flow path of said first heat exchanger in heat exchange relation with the charge air; and supplying the charge air from said first heat exchanger to a second heat exchanger in heat exchange relation with a gaseous coolant.
19. A charge air cooling method comprising the steps of supplying charge air to a first heat exchanger, circulating a liquid coolant through said first heat exchanger in heat exchange relation with the charge air; supplying the charge air from said first heat exchanger to a second heat exchanger; and supplying a flow of gaseous coolant to said second heat exchanger in heat exchange communication with the charge air.
20. In an engine system including an engine, a radiator, means for circulating liquid coolant between the engine and the radiator, and means for supplying charge air to the engine, a charge air cooling method comprising the steps of supplying the charge air to an air-to-liquid heat exchanger; circulating the liquid coolant between the radiator and the air-to-liquid heat exchanger in heat exchange relation with the charge air; supplying the charge air from the air-to-liquid heat exchanger to an air-to-air heat exchanger; supplying a flow of ambient air to the air-to-air heat exchanger in heat exchange relation with the charge air; and supplying the charge air from the air-to-air heat exchanger to the engine.
21. In an engine system including an engine, means for providing liquid coolant for cooling the engine, and means for supplying charge air to the engine, a method of cooling the charge air comprising the steps of passing the charge air in heat exchange relation with the liquid coolant to partially cool the charge air; and passing the partially cooled charge air in heat exchange relation with ambient air to further cool the charge air prior to supply to

the engine.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1980.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

PUB-NO: GB002023797A

DOCUMENT-IDENTIFIER: GB 2023797 A

TITLE: Charge air cooling systems

PUBN-DATE: January 3, 1980

ASSIGNEE-INFORMATION:

NAME	COUNTRY
GARRETT CORP	N/A

APPL-NO: GB07920872

APPL-DATE: June 15, 1979

PRIORITY-DATA: US91638878A (June 16, 1978)

INT-CL (IPC): F02B029/04

EUR-CL (EPC): F02B029/04 ; F02B029/04, F28D001/04

US-CL-CURRENT: 60/599

ABSTRACT:

CHG DATE=19990617 STATUS=O> A charge air cooler 44 for a turbocharged engine 12 comprises a first heat exchanger 46 which transfers heat from the charge air (in line 32) to the engine cooling water (in conduits 50, 52), and a second heat exchanger 48 which transfers heat from the charge air to ambient air.
<IMAGE>